modified by its proximity to the ocean and the prevalence of the alternating land and sea breezes. Although north of the Equator the highest day temperatures occur in the period December to May and the lowest during July to September. Night temperatures are fairly uniform throughout the year except for January and February when they are considerably lower than during the remaining months, probably on account of increased radiation due to absence of clouds and the drier condition of the atmosphere.

January has the greatest range between the day and night temperatures while the least occurs during the period June to September. The maximum temperature did not go higher than 91° during the entire period of 20 months observations and reached that point but 8 times.

Minimum temperatures range within a few degrees of 70° throughout the year, except from December to February, when they occasionally fall below 60°. A minimum temperature of 66° on the night of December 8, 1913, is referred to by the observer as a very cold night although in the following January readings as low as 58° were recorded.

The unusually low temperatures during these months are reported as occurring with dry north winds probably blowing from the Sahara, although their dry character is doubtless much modified during their passage over the intervening forests.

The characteristic wet and dry seasons of the Tropics are well defined in this section of the African coast. January probably has the least rainfall, only 0.10 inch falling during that month in 1914. December, February, and March likewise appear as months of light rainfall, the total for the four dry months constituting less than 3 per cent of the annual.

The wet season prevails from May to November, during which period rains are frequent and often heavy, as much as 6 to 8 inches falling in a single period of 24 hours. Considerable variation exists in the amounts during the same months of different years; for instance, June, 1913, had a total of 27.48 inches, while the same month of 1914 had slightly more than 50 inches. The total rainfall for the 12 months, July, 1913, to June, 1914, was more than 200 inches, a record probably equal to that of any other point along the coast.

During the rainy season precipitation is of almost daily occurrence, and cloudy weather prevails continuously for long periods. From July to October, 1913, inclusive, 123 days, rain occurred on all but 17 days.

During the drier period of the year there is much clear and pleasant weather, and the land and sea breezes occur at regular periods, the land breeze from about 11 p. m. to about 9 a. m. and the sea breeze for the remainder of the 24 hours.

TABLE 1.—*Summary of meteorological observations at Schiefflin, Liberia, May, 1913, to December, 1914.*

Months.	Temperature.							Precipitation.			Weather.		
	Mean maximum + mean minimum ÷ 2.	Mean maximum.	Mean minimum.	Highest.	Lowest.	Greatest daily range.	Mean daily range.	Total.	Greatest in 24 hours.	Number of days with 0.01 inch or more.	Clear.	Partly cloudy.	Cloudy.
1913.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	Inches.	Inches.	Days.	Days.	Days.	Days.
May	80.0	87.7	72.3	91	68	21	15.4	9.93	2.58	17	8	14	9
June	78.7	85.3	72.1	90	69	18	13.2	27.48	4.38	24	1	4	25
July	77.7	83.4	72.0	88	68	16	11.4	30.69	6.24	29	0	0	31
August	77.0	81.7	72.3	86	71	14	9.4	30.07	6.16	25	3	11	17
September	76.6	81.7	71.6	85	68	14	10.1	23.90	3.06	26	5	9	16
October	78.6	84.7	72.6	89	70	17	12.1	24.35	4.52	26	12	14	5
November	79.6	86.6	72.5	89	70	18	14.1	8.74	2.35	15	7	17	6
December	79.9	87.8	72.0	91	66	22	15.8	1.74	0.74	4	13	11	7
1914.													
January	77.8	87.5	68.2	91	58	31	18.7	0.10	0.10	1	16	10	5
February	78.9	87.6	70.2	91	65	24	17.8	1.84	1.84	1	15	8	5
March	80.1	88.2	72.0	91	68	21	16.2	1.29	0.48	6	18	8	5
April	79.8	87.9	71.6	91	70	19	16.3	8.76	2.43	14	25	5	0
May	79.4	87.3	71.6	90	69	20	15.6	19.70	3.85	23	8	22	1
June	78.0	82.6	73.3	87	70	15	9.3	50.35	7.50	29	5	13	12
July	75.3	79.3	71.3	84	69	12	8.0	13.25	3.20	23	3	6	22
August	75.8	80.3	71.3	85	68	17	8.9	14.46	2.95	20	6	9	16
September	76.8	81.6	72.1	84	69	13	9.5	26.43	3.04	28	6	14	10
October	78.1	83.6	72.6	87	69	14	11.0	31.66	4.02	30	7	14	10
November	78.7	85.0	72.4	88	69	17	12.6	13.90	2.50	23	12	14	4
December	79.8	88.2	71.5	90	61	28	16.7	4.43	2.77	8	14	15	2

MONTHLY WEATHER PERIODICITY.[1]

By VLADIMIR KÖPPEN.

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It is wonderful with what stubbornness does persist the belief that the moon must in some kind of a manner exercise a decisive influence on the weather and that the wicked, narrow-minded scholars simply refuse to recognize it. It is claimed that scholars refuse to investigate the matter, contenting themselves with discrediting the statements made by the "Unbiased" who do not belong to the profession.

Now, there could be no more welcome present to meteorologists, particularly to those who are charged with the duties of a forecaster, than such a simple key to the confusion that surrounds the weather's changes. How much pleasanter the task of weather forecasting if, by a glance at the moon's position as given in an astronomical ephemeris, one could ascertain the actual tendency of the weather to improve, to grow worse, perhaps even the tendency to a given pressure distribution, instead of having painfully to acquire a knowledge concerning the behavior of lows, etc., that still leaves so many possibilities open.

For this very reason there actually are no small number of scientific studies of a possible lunar influence on the weather. To be sure, the instigators of the repeatedly reappearing lunar systems of weather prophecy are usu-

[1] Preliminary communication; the full memoir will appear in the Archiv der Deutschen Seewarte.—*Author.*

ally wholly ignorant of the fact that, when there is such a complex cooperation of many causes which can not be sifted by experiment, the truth of the matter can only be demonstrated by discussing a sufficiently large amount of observational material by the aid of correct statistical methods. Such people prophesy wildly on the strength of some coincidence. They are usually quite lacking, also, in the proper self-criticism; in their eyes everything confirms their assumptions, and they willingly surrender themselves to their agreeable self-deception.

Nevertheless, the application of correct methods has brought out several points wherein there are signs of a lunar influence, and these must be further investigated. On the one hand these signs indicate an atmospheric tidal movement, very slight, to be sure, and of infinitesimal effect upon weather and wind, as are the daily barometric variations in any case. On the other hand they point to more or less considerable fluctuations of about one month's duration; the regularity of these swings leaves it an open question whether they belong with one of the periods of the lunar revolution or of the sun's rotation, for these have similar durations.

At present we will consider only these monthly variations. So far we have two fluctuations apparently so well supported by observations that it is desirable to analyze them exhaustively—viz, (1) the strong pressure variations of the synodal month falling in the last month of our year, discovered by G. Meyer and K. Seemann [2] in 1890; and (2) the variation in thunderstorm frequency also accompanying the synodal month, discovered by Luedicke [3] in 1875. The closer investigation of these two periodicities seems promising, because repeated investigations of long series of observations by different students have revealed their occurrence. Seemann and Meyer found the first while working independently on the series 1869–1886 and 1876–1889. After Luedicke had found the second case, it was again discovered (with a smaller amplitude, to be sure) in 1885 by the present writer [4] and later by Richter,[4] Hazen, Meyer, Gruss, Polis, and others,[5] as also in 1898 by Ekholm and Arrhenius.[6] I have sought to investigate these two problems as exhaustively as possible, utilizing all the published observations. After laying aside the consideration of the first problem, 18 years ago,[7] because of the internal contradictions in the results, the work has again advanced so far during the past months that it seems suited for at least a preliminary notice.

Seemann and Meyer had shown that during the years they investigated, the pressure over central Europe in the months September to January stood, on the average, almost 10 mm. (!) lower in the first days following full moon than it did in the first days after new moon. It remained to determine both the areal extent of this phenomenon (it could not possibly embrace the whole earth) and its behavior during other periods, for Seemann had found that it did not appear on the average during 1844–1875.

In order to contend with the tremendous amount of material on hand, it was necessary to employ the very simplest methods. Consequently no means were computed, but I simply counted the cases of positive and negative pressure departures from certain thresholds (Schwellen). Since 1876, and often earlier, the published meteorological records group the daily values into 5-day periods; it was therefore most convenient to group the counts into 5-day sections, the first new moon or full moon of the month falling in the middle of the first 5-day section and the following five coming in succession thereafter. This order was adhered to in each month, thus eliminating the shift of the synodal month so far as it was present. An example will illustrate the method:

TABLE 1.

THORSHAVN, 1885. Schwellen: 765 mm., 740 mm.

[Three observations daily.]*

Pentads..	1		2		3		4		5		6	
Schwellen.....	>65	<40	>65	<40	>65	<40	>65	<40	>65	<40	>65	<40
● 8 Oct.	......	......	12	......	10	......	......	2	2	6	......	2
● 6 Nov.	......	......	3	1	2	......	2	......	......	5	......	10
● Dec.	4	2	5	4	......	......	3	......	......	4	......	14
Sums....	4	2	20	5	12	0	5	2	2	15	0	26
	$\underbrace{\qquad}$ (a) 24−7=+17						$\underbrace{\qquad}$ (b) 7−17=−10					

*The three observations daily thus gave 15 observations in each pentad.

The compilation for 1875–1894 was the first made; it completely confirmed Meyer and Seemann's results and gave sharper limits for them. In the 20-year mean there regularly appears a standing pressure wave during these three months. Its crest appears over Scandinavia a few days after new moon, while its trough lies over Scandinavia and the North Sea a few days after "new moon" [full moon ?]. In Norway this rule is so strongly marked that the difference (a) − (b) at Bodö during these 20 years was almost always positive, as is shown by the following set of numbers:

TABLE 2.—*Difference (a)−(b) at Bodö, Norway.*

1875,	9,	1880,	8,	1885,	7,	1890,	24,
1876,	46,	1881,	13,	1886,	14,	1891,	1,
1877,	12,	1882,	61,	1887,	6,	1892,	1,
1878,	−5,	1883,	21,	1888,	37,	1893,	14,
1879,	19,	1884,	1,	1889,	15,	1894,	−12.

The amplitude of this variation decreases in all direc, tions from Norway; in southern Europe (San Fernando-Lesina), in the Ural and in West Greenland the difference is almost zero, while in Siberia it has the opposite sign signifying that on the average the pressure after full moon was there higher than after new moon. It is to be expected that such a compensation occurs somewhere, and it is a cause for regret that owing to the lack of published daily meteorological observations from America this phenomenon can not be traced farther.

As one rarely employs more than 20 years of records in such an investigation it might appear that the above has established an interesting periodicity. A computation of the errors would give a small probable error for the results. Nevertheless the periods before 1875 are wanting, as already stated. The question now arises: Does this appearance and disappearance form part of a longer periodicity? If this is the case, the result is a valuable one which might be used to a certain degree in practical weather forecasts. If the longer periodicity is wanting, then we face a strange accident from which no conclusions can be drawn for the future.

In resuming the investigation of this question, I therefore set myself the task of tracing this questionable relation through as many years as possible, and called on Dr. Burchard and Capt. Bachmann of the Deutsche Seewarte to assist me. I had already been struck by the fact that the magnitude of the variation, after being somewhat smoothed, seemed to point to a 6-year fluctuation. The recent beautiful results of the 11-year temperature period and Peterson's suppositions regarding the relation between sun-spot period and moon [8] encouraged me to

[2] Meteorologische Zeitschrift, November, 1890, 7: 427.
[3] Ztschr. d. Oesterr. Ges. f. Met., Wien, September, 1875, 10: 281.
[4] Meteorologische Zeitschrift, January, 1885, 2: 34–37; 307–310.
[5] *See* Namen- und Sachregister *of the* Meteorologische Zeitschrift.
[6] Handlingar, Svenska vetensk. ak., 31, No. 2.
[7] A brief communication on that portion of the investigation which deals with the Seemann-Meyer period as seen in the "Synoptischen Karten vom Nordatlantischen Ozean," appeared in Ann. d. Hydr. u. mar. Met., April, 1896.

[8] Annalen d. Hydr. u. mar. Meteorol., 1914: 214.

group my figures also according to the 11- and the $11\frac{1}{3}$-year periods. This treatment of European figures for the interval 1844–1912 yielded the following terminal sums for 11 years beginning with the mean minimum year of the sun spots:

Year 0	I	II	III	IV	V	VI	VII	VIII	IX	X
−1	5	11	4	1	0	7	−12	16	11	−15

Thus there are apparently two variations lasting, alternately, 8 and 3 years, which together gave the impression of a 6-year periodicity. In this connection it is noteworthy that the indicated period is not of the type 3, 8, 8, 3, 8, 8, . . . , summing 19 years, or the known lunar period of 19 or 18.6 years; but is rather of the type 3, 8, 3, 8, 3, . . Since the lunar phases return to approximately the same dates in 3, 8, and 11 years as well as in 19 years, the predominance of 3 and 8 year intervals might still indicate a cooperation of lunar and solar influences.

Unfortunately, however, all these clues are lost when one attempts to trace them through earlier years also. Useful barometric observations in Europe have been published for Basel since 1755 and for Vienna since 1775. I present here in Table 3 [A] the 10-year sums of the counts for 140 years of barometric observations at Vienna, simply to illustrate the behavior of the pressure. Pentad 1 begins two days before new moon; every figure is based on 30 pentads or 150 days.

Table 3 [A].—*The barometric march of the synodal month at Vienna (October to December) shown by means of the differences between the number of high and the number of low barometer readings.*

Years.	Pentads.					
	1	2	3	4	5	6
	●			○		
1775–1784	6	2	5	−9	9	−14
1785–1794	−10	4	4	−4	11	−6
1795–1804	22	−7	−15	5	−10	6
1805–1814	2	7	−47	16	20	3
1815–1824	8	−22	−20	19	8	5
1825–1834	21	16	−35	−11	0	9
1836–1844	23	28	5	−25	−31	−1
1845–1854	22	1	6	−27	0	7
1855–1864	−34	−2	29	1	−8	16
1865–1874	25	−6	−20	19	−29	11
1875–1884	51	−3	0	−16	−23	−7
1885–1894	0	18	−2	−21	3	4
1895–1904	−12	−16	−24	28	20	4
1905–1914	−36	21	−2	18	5	−6

By properly selecting the years all kinds of "lunar influences" may here be "demonstrated" by means of a material that would ordinarily be regarded as quite adequate therefor, i. e., with 10 to 20-year means. One may find here the simple pressure oscillation of the years 1835 to 1844, or the quite unsymmetrical one of 1895 to 1904, or the irregular double oscillation of 1865 to 1874 and 1905 to 1914, and again the displacement of the extremes throughout the month.

Since, however, the pressure excesses of pentads 1 and 2, as compared with 4 and 5 (appearing in the years 1875 to 1894 and also in 1835 to 1854) are probably the most interesting it is not inappropriate to present in Table 4 [B] the algebraic sums of these differences for the barometric observations at 1 to 10 European stations for each of the 60 years 1755 to 1814. The numbers before 1775 relate to Basel, those following to both Basel and Vienna; from 1781 on they include stations of the Mannheim Society until the latter ceased in 1792. London is included from 1795 on, and after 1809 I have always used at least 4 series which increases to at least 6 after 1822. From the superfluity of more recent observations I have selected only those places that gave the monthly variations from 1875 to 1894, which were mentioned at the beginning of this paper (p. 180a), i. e., from the region bounded by the line Vardö-Archangel-Petersburg-Warsaw-Vienna-Geneva-London-Styckisholm-Vardö, which also embraces the stations furnishing the older observations.

In Table 4 positive figures indicate that in the region above delimited, the barometer was higher in the 10 days at and after new moon than in the 10 days at and after full moon, on the average for the last three months of the year given. The negative figures indicate when the opposite was the case.

Table 4 [B].—*Relative numbers for the excess of the pressure at and after the time of new moon compared with the pressure at and after full moon.*

Years.	0	1	2	3	4	5	6	7	8	9	10-year sums.[1]		
											Arithmetic.		Algebraic.
											+	−	
1750						−2	4	−12	9	−29	13	43	−30
1760	−23	48	−12	4	−7	33	15	29	3	3	113	42	71
1770	−45	−21	−25	−9	−25	−13	47	−9	44	5	96	137	−41
1780	4	−11	−25	−14	−12	−38	21	−14	3	4	11	114	−103
1790	9	22	−13	9	−11	11	10	−3	9	−6	70	33	37
1800	56	1	−30	−21	−16	−14	−12	−22	−19	−4	57	138	−81
1810	−5	−4	−2	27	1	37	7	6	−1	−11	78	23	55
1820	3	−45	−5	−15	−4	13	−24	3	−6	0	19	99	−80
1830	11	−22	5	−4	0	4	−8	−13	12	−6	32	53	−21
1840	29	−33	36	12	−33	−3	−27	−9	−2	21	98	107	9
1850	33	−9	10	10	−11	5	−5	4	25	−38	87	63	24
1860	−15	−11	−28	−5	32	−8	−13	5	7	16	60	80	−20
1870	12	22	5	−21	−15	23	20	10	−2	8	100	38	62
1880	16	−4	21	17	0	12	35	3	14	5	123	4	119
1890	3	6	9	3	7	20	−17	11	21	−30	80	47	33
1900	2	−15	−3	7	−18	−6	17	−23	20	14	60	65	−5
1910	−21	−20	11										

[1] Computed and added by the translator.

Again, on looking through Table 4 one finds many apparent regularities that persist through a certain series of years, but there are none that run through the whole period of 158 years. The 10-year sums at the right-hand side of Table 4 present, between 1875 and 1895, a very significant series of figures having like sign almost without interruption. Their parallel is not to be found elsewhere in this table, among either the positive or the negative values. There is almost no trace of a long-period recurrence of this series.

What shall one think of such confusion? This apparent monthly pressure change which persists through a certain number of years, together with its disappearance or shifting of its maxima and minima, is meaningless to us. Should we perhaps ascribe it, not to the lunar motions but rather to the rotation of the sun, on whose surface active (e. g., hotter) areas can persist for a series of years and then disappear? But what evidence have we for such an explanation?

Many adherents of the moon theory will say: "Well, then, if the synodal revolution does not cause it, then perhaps one of the others does." But at least one of these other motions, the periodic or sidereal, is contained in these figures because they apply only to one season of the year and the relation of the two periods is the same at intervals of a year. The investigation seems still more unpromising if carried out for the other seasons, because Meyer and Seemann found no regularities in them either. Nevertheless I have carried it out for them also, although for only a few observing stations, but shall not here notice the results; besides, they have turned out negatively.

However much it is to be regretted that these extensive comparisons fail to reveal any regularities, their publication will at least furnish an arsenal of material for use in the exact testing of the perennial crop of new variants on the contention that the weather is controlled by our obviously and oh, *so* innocent satellite.